BEDLOAD TRAPS: A NEW SAMPLER FOR SAMPLING BEDLOAD IN MOUNTAIN STREAMS

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Abstract The Forest Service and Colorado State University have cooperatively developed a portable bedload sampler specifically designed to collect gravel and cobble-bedload (4 to 180 mm in diameter) in wadeable mountain streams. The bedload traps were specifically designed to meet the sampling challenges that occur in mountain coarse gravel- and cobble-bed streams: coarse bedload can comprise a wide range of particle sizes (2 – 256 mm), can be as low as one 4 mm gravel particle per hour but can also amount to 10 kg in a few minutes. Gravel transport rates vary not only by about 6 orders of magnitude over a highflow season, but may also rapidly fluctuate over time. Bedload traps consist of an aluminum frame with 0.3 by 0.2 m opening to which a 1 – 1.6 m long net with a 4 mm mesh width is attached that collects the bedload. The 4 mm mesh lets flow pass the net with relatively minor deceleration, whereas acceleration of the near-bottom flow on the smooth ground plate in front of the bedload trap entrance helps to ensure that particles on the ground plate enter the trap entrance. Bedload traps are unique in that they are fastened onto ground plates anchored to the stream bottom. Ground plates avoid direct contact of the sampler with the stream bottom. This feature prevents sampler perching as well as involuntary particle pick up from the bed during sampler placement or removal, a major source of error for samplers that are placed directly onto the gravel bed. Not being handheld and having a large volumetric sample capacity permits long deployment times of about one hour. This is needed to integrate over short-term fluctuations of flow and to sample the infrequently moving, larger particle sizes in motion.

Typically, 4-6 bedload traps are installed across the stream width spaced by 1-2 m. Bedload traps can be operated in wadeable flow, up to approximately 80 to140% of bankfull in mountain gravel-bed streams, depending on stream size and local cross-section width. Bedload traps are emptied by untying the back end of the net, shaking the sample into a bucket, and retying the net. Because bedload traps remains in place, samples are collected continuously back-to-back over a field day, providing not only many consecutive samples but also freeing the operators do other things while the bedload traps are sampling.

Since 1998, we have measured gravel bedload transport rates at ten study sites in coarse-bedded mountain streams in the West using bedload traps and a handheld 3-inch Helley-Smith (HS) sampler side-by-side. Compared to a standard deployment of a handheld HS sampler, the bedload trap design helps to avoid several of the intrinsic HS limitations, specifically: 1) involuntary particle pick-up that causes the HS to oversample at low flows or 2) perching on coarse particles that can cause the HS to undersample at any flow; 3) the difficulty to collect large particles due to the small HS entrance size that causes the HS to undersample at high flows;

4) Bedload traps avoid the short 0.5-2 min HS sampling time that causes the HS to overpredict transport rates when transport is low and underpredict transport rates when transport is high.

Bedload traps, in our opinion, properly characterize the nature of gravel transport in coarse mountain streams. The high quality of the data produced by bedload traps has enabled us to observe and document several attributes of bedload transport in mountain gravel bed rivers that had been unknown or only hinted by previous research. Among our findings:

1. Rating and flow competence curves in mountain gravel- and cobble-bed streams are mainly straight in log-log space and can be described by power functions ($Q_b = aQ^b$; $D_{max} = cQ^d$).

2. Rating and flow competence curves are steep in mountain gravel- and cobble-bed streams; streams with steep rating curves have steep flow competence curves while streams with large bankfull D_{max} particle sizes have large bankfull transport rates. Rating curve exponents ranged from 7 – 16 (similar results were obtained by other non-HS studies) which is about 3.5 times steeper than HS-measured rating curves. The rating curve steepness has implications for calculations of effective discharge and annual transport estimations. Flow competence curve exponents were 1.3 – 3.5, approximately 2.5 times steeper than HS sampled curves. This result has implications for incipient motion computations.

3. Exponents and coefficients of the bedload rating and flow competence curves are well correlated to the subsurface percent of fines, bed armoring, and channel width. This permits a direct estimate of rating and flow competence exponents and coefficients from bedmaterial and channel parameters. With further development, these relationships could circumvent the necessity for bedload transport and incipient motion equations—both of which give notoriously poor results in steep mountain streams.

4. Rating curves for individual gravel size-fractions generally run parallel to each other, indicating near-constant ratios of transport rates among mobile size classes over a wide range of flow for a given stream. Among streams, the ratios of transport in specified size fractions can differ.

5. Because bedload traps provide back-to-back samples, traps have enabled us to observe both daily and seasonal hysteresis. In most cases, transport exhibits a counter-clockwise hysteresis, indicating a depletion of sediment supply. An exception was found in Little Granite Creek WY, where a mud-algea crust artificially retarded bedload motion.

6. Bedload trap results can be evaluated for each trap individually, enabling documentation of lateral variability in bedload transport. Looking at the transport collected by an individual trap as part of a multiple trap cross-section showed us that the majority of transport does not follow the thalweg, but rather follows an independent, sinuous path from the head of one (submerged) point gravel bar to the next bar-head downstream.

7. The flow competence curves generated from bedload trap data showed that the bankfull particle mobility in mountain gravel-bed streams approximates the D_{50} bed surface size in fairly mobile gravel beds but decreases to ½ to $^1/_5$ of bed D_{50} size in plane-bed and step-pool

streams. Shields values computed from field measured bankfull mobile particle sizes may be 10 times higher than the original Shields value, the use of which overpredicts the bankfull mobile particle size by a factor of 10.